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A COMPUTERIZED TEST OF SELF-CONTROL PREDICTS CLASSROOM BEHAVIOR

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We assessed choices on a computerized test of self-control (CTSC) for a group of children with features of attention deficit hyperactivity disorder (ADHD) and a group of controls. Thirty boys participated in the study. Fifteen of the children had been rated by their parents as hyperactive and inattentive, and 15 were age- and gender-matched controls in the same classroom. The children were observed in the classroom for three consecutive mornings, and data were collected on their activity levels and attention. The CTSC consisted of two tasks. In the delay condition, children chose to receive three rewards after a delay of 60 s or one reward immediately. In the task-difficulty condition, the children chose to complete a difficult math problem and receive three rewards or complete an easier problem for one reward. The children with ADHD features made more impulsive choices than their peers during both conditions, and these choices correlated with measures of their activity and attention in the classroom.

DESCRIPTORS: self-control, impulsivity, attention deficit hyperactivity disorder, hyperactivity, concurrent schedules, computer assessment

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Attention deficit hyperactivity disorder (ADHD) is a serious condition that affects 3% to 7% of children between the ages of 6 and 11 years (American Psychiatric Association, 1994). Children with ADHD have significant levels of inattention, hyperactivity, and impulsivity. They have trouble completing schoolwork and maintaining friendships. They are also at increased risk to break the law and suffer from drug addiction (Barkley, 1988). Although the exact causes of ADHD are unknown, specific neurological abnormalities and genetic factors have been suggested as causal agents in the disorder (Barkley, 1997).

Barkley has proposed a neurodevelopmental model of ADHD that describes the primary symptom of ADHD as a deficit of behavioral inhibition. According to Barkley, behavioral inhibition involves three interrelated processes: (a) inhibition of impulses to respond to immediate rewards or avoid unpleasant events; (b) cessation of an ongoing pattern of behavior to permit decision making; and (c) inhibition of impulses to interrupt self-directed activity. Thus, the principal impairment in ADHD is believed to be a deficit in impulse control in which the clinical profile comprises a continuum of behaviors that can include pervasive fidgeting, frequent activity changes, excessive talking and motor movements, failure to complete tasks or follow through on instructions, and problems with short-term memory, academic performance, and social relationships.

Behavioral researchers have studied the problem of impulsive behavior in the context of a behavioral model of self-control. In this

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model, a choice between a small reward available after a short delay (SSR) is presented concurrently with a choice of a larger reward available after a longer delay (LLR). Choosing SSR over LLR is considered impulsive because the larger amount of reinforcement is forfeited in favor of the smaller, more immediate reward (Rachlin & Green, 1972). By contrast, choosing LLR over SSR is considered a restrained or self-controlled choice because the value of the larger reward is not sharply discounted by the delay to reinforcement (Rachlin, 1989).

Numerous studies have found that children with ADHD are more likely than their peers to prefer SSR over LLR. Schweitzer and Sulzer-Azaroff (1995) presented 6-year old boys with a choice to receive three coins after a 16-s delay or one coin immediately. The coins were exchangeable for toys at the end of the session. The children with ADHD were more likely to choose the immediate reward than were typically developing children. Sonuga-Barke, Taylor, Sembi, and Smith (1992) gave hyperactive children and a control group of same-age peers a choice between one token that was available immediately or three tokens that were available after a 30-s delay. When there were a fixed number of trials and no postreinforcement delay, hyperactive children were more likely to choose the immediate token than were their peers. When a postreinforcement delay was used to keep trial length constant, both ADHD children and typically developing children chose the delayed reward. Sonuga-Barke et al. suggested that hyperactive children prefer an overall shorter session length instead of a larger amount of total reward. Other researchers have consistently found that children with ADHD have an initial preference for immediate over delayed rewards (Binder, Dixon, & Ghezzi, 2000; Neef, Bicard, & Endo, 2001; Schweitzer & Sulzer-Azaroff, 1988; Solanto et al., 2001).

Recent research has extended the range of variables examined in the self-control model for children with ADHD. Neef et al. (2001) developed a computer-based assessment methodology that measured preference for high- versus low-rate reinforcement, high- versus low-quality reinforcement, immediate versus delayed reinforcement, and high versus low response effort required to produce reinforcement. When sensitivity to each variable was assessed in isolation, the children with ADHD chose higher rate reinforcement, higher quality reinforcement, immediate reinforcement, and low response effort to obtain reinforcement. However, when choice of variables was placed in competition with each other (e.g., immediate reinforcement vs. higher quality reinforcement), the 3 participants chose immediate reinforcement over delayed reinforcement even when delayed reinforcement occurred at a higher rate, was of higher quality, or required less response effort to obtain. Neef, Marckel, et al. (2005) replicated and extended this work to a group of 32 children who had been diagnosed with ADHD and 24 children without the diagnosis. The assessment methodology distinguished those with and without ADHD, showing that those with the diagnosis most often chose the option that yielded immediate reinforcement at the expense of higher quality reinforcers, higher rate reinforcement, and lower response requirements to obtain reinforcement. By contrast, children without ADHD showed consistent preference for higher quality reinforcement rather than more immediate reinforcement, higher rate reinforcement, or easier math problems to perform.

All of the studies cited above have employed analogue or laboratory-based assessments. Some of the studies have used arbitrary responses such as mouse clicks on symbols (Solanto et al., 2001), whereas others have used clinically relevant behaviors such as arithmetic problems (Neef et al., 2001; Neef, Marckel, et al., 2005). Although direct measurement of impulsivity using the self-control paradigm is both objective and precise compared to subjective rating scales

(Conners, 1990), laboratory measures will have limited applied value or ecological validity if they do not correspond to or predict behavior characteristic of ADHD in natural, uncontrolled environments (Barkley, 1991; Solanto et al., 2001).

We are aware of only one study that has addressed the extent to which laboratory assessments of impulsivity and self-control predict behaviors in natural environments that are indicative of inattention and hyperactivity, and that differentiate children with and without ADHD. Solanto et al. (2001) conducted two types of laboratory assessments on children with ADHD and on a group of control children. The first test was the stop signal task, which is a visual reaction-time task in which children first learn to react quickly to a visual stimulus and then later refrain from this reaction (see Solanto et al. for a description of the procedural details). The second test was the choice delay task that required children to choose between a one-point reward delayed by 2 s and a two-point reward delayed by 30 s. Points were earned for correctly positioning a mouse pointer to one of two different-colored squares on a computer screen and were exchanged for money after each two-trial block. To examine whether laboratory measures of impulsivity and self-control correlated with behavior in natural environments, 16 min of classroom observations were conducted for the children with ADHD who participated in the laboratory tests. Observational data also were obtained for a set of comparison children without ADHD in the same classroom, but who were not given the laboratory tests. A 15-s partial-interval recording method was used to obtain data on gross motor behavior, interfering behavior (various disruptive behaviors), off-task behavior, and physical aggression. Solanto et al. found that children's choices on the laboratory delay task differentiated children with ADHD from controls. They also found that choices on the delay task correlated significantly with interfering behaviors ($r = -.375$), gross motor behavior ($r = -.355$), and physical aggression ($r = -.395$) but were not significantly correlated with inattention.

The present study was designed to extend Solanto et al. (2001) in the following ways. First, in addition to a test of sensitivity to reward delay, we included a test of sensitivity to task difficulty (cf. response effort; Neef et al., 2001). Although few participants in Neef's studies demonstrated primary sensitivity to task difficulty (Neef et al., 2001; Neef, Bicard, et al., 2005; Neef, Marckel, et al., 2005), the variable does conceptually represent impulsivity, which is believed to be the principal impairment in ADHD (Barkley, 1997). That is, choices that suggest that task difficulty discounts the value of a larger reward are analogous to those that show that delayed reinforcement produces similar discounts. Second, we assessed sensitivity to reward delay and task difficulty using clinically relevant behaviors (completion of arithmetic problems) in the context of an attractive computer game with animation similar to that in Neef's studies. We hypothesized that clinically relevant test behaviors would be better predictors of inattention, hyperactivity, and disruptive behavior in natural environments compared to mouse clicks on arbitrary shapes (Solanto et al., 2001). Third, we observed behavior in the classroom for an average of 250 min per child (cf. Solanto et al., 16 min per child on a single day) across 3 consecutive days to obtain a more representative sample of behavior. The data were collected simultaneously on test and control children in the same classroom to control for momentary differences in activities. All control children also participated in the laboratory tests to allow correlation between their laboratory measures and classroom behavior. Finally, Solanto et al. used secondary reinforcers (nickels), which increased the delay to the back-up reinforcer. The present study employed a choice among nine primary reinforcers (food or toys) and one

secondary reinforcer (money) at the beginning of each trial to avoid an indeterminate delay to obtain the back-up reinforcer (Hyten, Madden, & Field, 1994).

METHOD

Participants

Thirty boys, all Caucasian and enrolled in regular education, participated in the study. Fifteen of them had been rated by their parents and teachers as exhibiting above-average hyperactivity and inattention. These children were categorized as test participants and had been referred by the Child and Adolescent Mental Health Services of the North Wales NHS Trust or by the child's school. The children's parents and teachers completed the Conners' Parent or Teacher Rating Scale—Long: Revised (see Table 1). Six of the 15 children had a diagnosis of ADHD. Although this is less than half of the sample, it does not accurately represent the severity of the symptoms shown by the remaining 9 children. It is the practice of the local health authority not to diagnose children with ADHD because of concerns that the label may promote teacher bias. The direct measures of the children's behavior in the classroom confirmed parent and teacher accounts that the children exhibited high levels of inattention and hyperactivity. The mean age of the test participants was 7 years 3 months; the children ranged in age from 5 years 2 months to 9 years 1 month. None of the children received any stimulant medication or received special education services.

Fifteen control children were classmates of the test participants. They were matched to the test participants on age, gender, and classroom. The control participants were described by their classroom teachers as exhibiting typical levels of activity and attention. The teachers of the control children completed the Conners' Teachers Rating Scale—Revised: Long Version. The parent scales were not completed because it was not always possible to arrange a face-to-face meeting with these parents. All control children received scores indicating that they were not at risk for a diagnosis of ADHD (see Table 1). The mean age of the control children was 7 years 5 months, and they ranged in age from 5 years 1 month to 9 years 4 months.

Informed consent for the test children was obtained in a meeting between the experimenter and the child's parents. Consent was obtained for the control children by means of a letter and permission slip sent home with the child from school. All of the children attended Welsh–English bilingual schools, and all were fluent in English.

Setting and Apparatus

The study was conducted in the children's schools. Behavioral observations were conducted in the children's classrooms. Each class consisted of 15 to 30 children. The children sat at tables with 2 to 3 other children. None of the test–control pairs sat at the same table.

The computerized assessment was conducted in an empty classroom or library on a laptop computer with a touchscreen. A red curtain was hung behind the computer to shield an experimenter who passed the rewards to the children. There were no clocks or time-keeping devices in the room.

Preference Assessment

A preference assessment was conducted prior to the first CTSC session. The experimenter sat at a table across from the child and presented photographs of 15 food items. The child selected his most preferred item by handing a card to the experimenter; this was repeated until he had chosen six items. These choices were programmed into the computer as rewards, which also included 5-pence coins, crayons, stickers, and colored pencils. A preference assessment was not conducted on the nonfood items because we did not have a large range of nonedible reinforcers. The child could choose among 10 possible rewards, including his most preferred items, at the start of each trial.

Table 1
Parent and Teacher Reports of ADHD Symptoms on the Conners' Rating Scale—Long: Revised

	Parents' ADHD index	Parents' *DSM-IV* total	Teachers' ADHD index	Teachers' *DSM-IV* total
Test				
M	74.8	72.4	70.9	74.2
SD	15.96	11.4	12.3	11.19
Control				
M			43.0	42.7
SD			2.43	2.5

Note. The means are represented as *t* scores. *t* scores below 45 indicate that the child is at low risk for ADHD. A *t* score above 61 places the child in the 86th percentile for that category and indicates a possible significant problem. A *t* score above 66 is indicative of a significant problem and places the child in the top 95th percentile of children for the category.

Math Test

We presented the children with a series of paper-and-pencil math problems to determine their ability levels and accuracy rates. Children were given a math test with a minimum of four examples of each level of problem depicted in Table 2. Difficult problems were defined as those the children were able to answer correctly between 68% and 83% of the time. Easy problems were those answered correctly 100% of the time. In the delay condition, the children were asked questions individually defined as easy. In the problem-difficulty condition, difficult problems were presented along with easy problems to test sensitivity to problem difficulty.

Computerized Test of Self-Control

All children participated in four sessions of the CTSC—two sessions on the delay condition and two sessions on the problem-difficulty condition. The participants experienced each type of task twice because previous research has found that children with ADHD are more likely to make impulsive choices on a second session of testing (Schweitzer & Sulzer-Azaroff, 1995). The contingencies for the two tasks of each type were identical, but the problems that the children answered varied. One session was conducted per day, and the students typically participated in two sessions per week for 2 weeks.

Table 2
The Levels of Problem Difficulty in the Math Test

Level 1	Matching identical numbers and letters
Level 2	Sequencing numbers
Level 3	Sequencing letters
Level 4	Addition of 1 and a single digit
Level 5	Single digit addition with the sum less than 10
Level 6	Single digit addition with the sum between 10 and 18
Level 7	Addition of a single digit and a double digit with no carrying
Level 8	Addition of two double digits with no carrying
Level 9	Addition of two double digits with carrying
Level 10	Addition of two triple digits with carrying

Delay condition. The delay condition of the CTSC assessed children's preference for LLR. The children could choose to answer a math problem and receive one treat immediately, or answer the same math problem and receive three treats after a delay of 60 s. The children needed to answer the problem correctly to receive the treats. Data were collected on the number of delay choices the children made.

Prior to the first session, the experimenter removed watches or time-keeping devices from the child so he could not measure time during the delay and then read the following instructions:

> Today you can earn some treats by doing math problems. You will have 14 turns to earn treats. Can you tell me how many turns you have? [The experimenter waited for the child to respond, and repeated the instructions if he could not answer correctly.] For the first 4 turns you won't get any choices; you should just answer the question on the screen. But after that, that you can choose which problem you want to do, and if you want to work for 1 or 3 treats. You can eat your treats right away or

Figure 1. Illustration of reward selection before the start of each block of 10 choice trials.

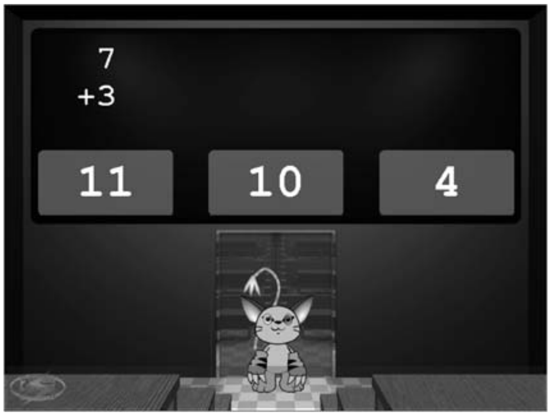

Figure 2. Illustration of a sample problem and three possible alternatives.

> save them for later. It's up to you. To start, you need to listen to the computer program and click the buttons on the screen. I will not be able to talk to you at all once the computer starts. Even if you try to talk to me or ask me questions I won't be able to answer. Are you ready?

Before the each subsequent session the experimenter said to the child, "This will be very similar to last time. You still have 14 turns. Can you tell me how many turns you have?" The experimenter gave the child paper and a pencil to assist with the math problems and a small bag to hold the rewards if he chose to save them. At the beginning of the computer program, an animated cat welcomed the participant to the game and stated that the purpose of the game was to do math problems to earn treats. Pictures of the 10 rewards appeared on the top of the screen (see Figure 1). If the child's parents gave permission for the child to receive only five to nine rewards, some of the items were duplicated. The cat said, "Here are some treats you can work for. Press the one you want to work for."

Above the delayed choice box was a picture of three pieces of the chosen reward, and above the immediate choice box was a picture of one piece of the same item. The cat said, "If you do the red problem, you can have three of them after you wait a little while, or you can do the yellow problem and get one of them right away." The screen went blank for 1 s and reappeared with only one problem and its corresponding reward available on either the left or right side of the screen. The side on which the problem appeared was counterbalanced.

The first four trials were no choice; only one of the colored boxes and its corresponding reward were available on the screen. The child was prompted to click on the problem. On the following screen, the math problem appeared on the top left of the screen, and three possible solutions appeared across the bottom (see Figure 2). If the child selected the correct answer, the cat appeared on the screen and said, "That's the right answer. You've earned 3 [1] treats. I'll set my clock and as soon as it beeps you can have your treats." The computer beeped after the appropriate amount of time, and an experimenter passed the treats to the child from under the curtain.

If the child selected an incorrect answer to the problem, the cat appeared on the screen and said, "No, that's not the right answer. Let's do another problem." None of the children answered more than three problems incorrectly during a session. The order and side of the presentation of the no-choice trials were counterbalanced. A postreinforcer delay was not used. Although research has found that children with ADHD continue to show a pref-

erence for SSR when the intertrial interval is kept constant (Neef et al., 2001), Sonuga-Barke et al. (1992) found that not using a postreinforcer delay was the most effective method to distinguish children with ADHD from their typically developing peers.

Following the no-choice trials were 10 choice trials. The cat prefaced the trials by saying, "Now you can do whatever problem you want. Let's begin." The child chose a reward from 10 choices before the start of each trial, and the different-colored boxes both appeared on the screen and contained identical math problems. Following the 10th trial, the cat said, "That's all for today. Good-bye." and the screen went blank.

Problem-difficulty condition. The same computer interface and procedures were used during the problem-difficulty condition. The child chose to receive three treats for correctly answering a difficult math problem or one treat for correctly answering an easy math problem. There were four no-choice trials and 10 choice trials. The easy math problem appeared in a green box, and the difficult math problem appeared in a purple box. The rewards were given as soon as the child correctly answered the question.

Direct Observation

Data on classroom behavior were collected for 3 consecutive mornings for each pair of children using an audiotape player with headphones that indicated 10-s intervals. The observers sat in a corner of the room and collected data between 9:00 a.m. and 12:00 p.m. Data were collected only during lesson time (when the children were assigned seatwork or when the teacher was giving verbal instructions). Data were not collected when either child was receiving one-to-one attention from an adult, during the children's play time, during classroom transitions, or when the observers could not see both of the children.

The following behaviors were recorded for both children in the pair at the same time using a 10-s partial-interval procedure: (a) gross motor activity: any movement of feet across the floor, when the shoulders touched the floor, or when the chair had two feet off the ground; (b) inattention: engagement in an activity other than the assigned task; (c) inappropriate use of materials: manipulation of an object in a manner that interfered with completing schoolwork (e.g., making drumming noises with pencils); (d) inappropriate vocalizations: audible speech when the rest of the class was silent or speaking without permission. These classifications were not mutually exclusive (e.g., a child who was talking to a classmate during a lesson was scored as engaging in inappropriate vocalizations and inattention).

All of the primary data were recorded by a trained graduate student in psychology, and interobserver agreement data were collected by the primary researcher with trained undergraduate psychology students for 33% of the sessions for each pair of children. The average total, occurrence, and nonoccurrence agreements were calculated for each interval by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100%. Occurrence agreement for all of the behaviours across all of the sessions was 93%, nonoccurrence agreement was 96%, and the total agreement was 96%.

RESULTS

Computerized Test of Self-Control

Delay task. The mean numbers of self-controlled choices each group made during both days of the delay task are presented in Table 3 along with the standard deviations. The self-controlled choice was a choice of the larger, delayed reward. The test participants made fewer choices of the LLR than did the control participants on both days. Results of a repeated measures analysis of variance (ANOVA), with a within-subject factor of day (two levels) and a between-subject factor of subject type (two levels), revealed a significant main effect of

Table 3
Mean Number of Choices of the LLR Each Group Made During the Delay and Problem-Difficulty Sessions on the Computerized Test of Self-Control

	Test		Control	
	M	*SD*	*M*	*SD*
Delay				
Day 1	6.4	2.2	7.4	2.5
Day 2	5.6	3.1	7.8	2.6
Total	11		15.2	
Problem difficulty				
Day 1	7.2	2.8	9	1
Day 2	5.8	2.6	9	1.5
Total	13		18	

subject type, $F(1, 28) = 4.02$, $p = .05$. There was no main effect for day and no interaction between day and subject type. Although the control children made more choices of the LLR on Day 2 than on Day 1 and the test children made fewer, this difference was not statistically significant. On average, the test participants answered 8.8 of the problems correctly, and the control children answered 8.6 of the problems correctly; this difference was not statistically significant.

Problem-difficulty task. The mean numbers of times the children chose the difficult math problem for each day of testing are also shown in Table 3. A repeated measures ANOVA revealed a main effect for subject type, $F(1, 28) = 10.9$, $p < .01$; the test children chose the easy problems that resulted in fewer rewards more often than did the control children. There was also a significant main effect for day, $F(1, 28) = 4.54$, $p < .05$. Table 3 shows that the control children were equally likely to choose the hard problem during both sessions, whereas the test children chose the hard problem more often on Day 1 than Day 2. The test participants answered an average of 7.47 of the math problems correctly, and the control children answered an average of 8.84 of the problems correctly. This difference was not statistically significant.

Table 4
Number of Intervals Each Group of Children Engaged in Target Behaviors Across 3 Days of Observation

	Test		Control	
Day	*M*	*SD*	*M*	*SD*
Gross motor				
1	11.9	4.3	3.9	2.3
2	14.3	7.3	2.5	2.1
3	14.5	8.2	3.5	1.9
Inappropriate vocalization				
1	20.4	9.5	6.6	3.8
2	20.7	8.1	7.4	5.4
3	22.8	10.3	7.2	5.1
Inattention				
1	29.0	11.9	9.9	6.8
2	28.3	9.5	10.7	9.1
3	30.7	9.8	10.1	5.1
Inappropriate use of materials				
1	9.4	6.9	2.3	3.3
2	9.6	3.9	2.1	2.6
3	9.4	4.5	2.1	2.5

Classroom Behavior

Table 4 shows the means and standard deviations for the percentage of intervals each group of children engaged in gross motor activity, inappropriate vocalizations, inattention, and inappropriate use of materials. Data were collected on 3 consecutive mornings. An average of 505 10-s intervals (84 min) of classroom observation was recorded each day. The test children showed higher rates on every measured behavior than did their matched controls. One-tailed independent *t* tests revealed that the test participants exhibited significantly more gross motor behavior, $t(28) = 7.09$, $p < .01$; inappropriate vocalizations, $t(28) = 6.18$, $p < .01$; inattention, $t(28) = 8.111$, $p < .01$; and inappropriate use of materials, $t(28) = 4.343$, $p < .01$; than did the control participants.

Relationship Between CTSC and Classroom Behavior

Pearson's correlations showed that the children's choices of larger rewards during the delay task significantly correlated with gross motor activity in the classroom, but not with inappropriate vocalizations, inattention, or in-

Table 5
Correlations Between Children's Choices of Larger Delayed Rewards on the Computer Task and the Average Number of Intervals They Engaged in the Observed Behaviors. The Data are the Average Responses and Behaviors of Both Groups

	Self-control choices on the delay task	Self-control choices on the problem-difficulty task
Gross motor	$r = -.357$ $p = .026^*$	$r = -.488$ $p < .01^*$
Inappropriate use of materials	$r = -.160$ $p = .4$	$r = -.661$ $p < .01^*$
Inappropriate vocalizations	$r = -.293$ $p = .116$	$r = -.461$ $p = .01^*$
Inattention	r = −.247 $p = .188$	$r = -.512$ $p < .01^*$

* Denotes statistical significance.

appropriate use of materials. The children's choices on the problem-difficulty task showed significant correlation with all four behaviors. (See Table 5 for the correlations for the entire sample of children.)

Representative Individual Data

Tables 6 and 7 show individual data for a representative subset of the entire study group. We calculated the difference between the test and control children's choices of the larger reward across all four CTSC sessions and ranked these difference scores from highest to lowest. The data from pairs with scores in the middle of the range (6 through 10) are shown in Tables 6 and 7.

Delay condition. The control participants in Pairs B, C, D, and E all made more or equal choices of the LLR than the test participants in every session. The test participant in Pair A made 10 choices of the LLR on Day 1 but reversed his preference completely on Day 2. Across both sessions, the control participant in Pair A chose the LLR more often than the test participant did.

Problem-difficulty condition. For Pairs A, B, and E, the control participants made more or equal choices of the difficult math problem than did the test participants in every session. For Pairs C and D, the test participants chose the difficult problem more often than the control for one of the sessions, but across both sessions the control participants chose to perform the difficult problem that resulted in greater reward more often than the test participants did.

Classroom behavior. The test participants engaged in more of all the observed behaviors than did their matched controls in the same

Table 6
The Number of Choices of the Larger Reward the Participants Made on the Delay and Problem-Difficulty Conditions. These Data Represent the Scores of the Middle Five Pairs of Participants

	Pair A		Pair B		Pair C		Pair D		Pair E	
	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
Delay										
Day 1	10	5	7	10	7	10	7	7	5	10
Day 2	0	6	8	9	9	10	2	9	6	10
Total	10	11	15	19	16	20	9	15	11	20
Problem difficulty										
Day 1	8	8	7	7	9	8	7	10	9	9
Day 2	2	5	6	8	5	9	8	7	6	10
Total	10	13	13	15	14	17	15	17	15	19

Table 7

The Average Number of 10-s Intervals the Participants Engaged in the Target Behaviors. These Data Represent the Scores of the Middle Five Pairs of Participants

	Pair A		Pair B		Pair C		Pair D		Pair E	
	Test	Control	Test	Control	Test	Control	Test	Control	Test	Control
Gross motor										
1	7.6	0.4	24.3	3.2	8.5	1.3	15.2	5.2	20	1.1
2	2.6	0.7	26.3	6.2	14.7	15	13.7	6.1	7.2	1
3	1.8	0.8	23.2	5.5	23.5	1.9	21.3	5.2	14.6	2.5
Inappropriate vocalization										
1	38.5	11	16.5	2.8	10.5	7.4	27.7	6.6	16.4	2.2
2	32.3	9.8	7.5	7.5	22.1	6.7	30.1	7.3	11.4	4.2
3	49.6	23.2	10.4	3.4	17	5.6	24.2	6.4	8.3	3.7
Inattention										
1	42.1	16.3	36	7.2	21.4	5.5	42.3	13.9	10.1	1
2	28	11.4	23.6	12.3	38.9	11	34.1	10.5	12.2	3.8
3	48.5	17.2	29.8	11.8	15.2	12.7	29.7	10.3	23.8	3.3
Inappropriate use of materials										
1	9.1	1.3	11.2	4.7	9	0.7	5	0	8.9	1
2	8.4	1	10.5	4.2	23.4	2.2	1.2	1.1	3	1.9
3	11	0	6.2	4.8	10.9	0	3.3	2.0	5.6	0

classroom on each of the 3 consecutive days of observation (see Table 7).

Predicting Classroom Behavior

A Fisher's Z transformation was calculated to compare the difference between correlations of Conners' ratings and classroom behavior and correlations of CTSC scores and classroom behavior. The Z transformations were not significant for gross motor behavior, inappropriate vocalizations, or inattention. However, the CTSC was significantly better at predicting inappropriate use of materials than were the Conners' rating scales ($Z = 1.69$, $p < .05$).

DISCUSSION

Direct measures of behavior obtained in the classroom indicated that children rated by their parents as exhibiting high activity levels and inattention engaged in significantly more episodes of gross motor behavior, inappropriate vocalizations, inappropriate use of materials, and inattention than their typical peers. In addition, children who exhibited these behaviors in the classroom were more likely than their peers to make choices that resulted in less overall reward on a computerized test of self-control. The children with ADHD features were more likely to choose small immediate rewards and were more likely to choose to complete easy math problems for less reward than more difficult math problems for greater reward.

In the current study, children with ADHD features were more likely than their peers to choose one treat after a short delay rather than three treats after a delay of 1 min. This finding replicates previous research that suggests that children with ADHD are impulsive or delay averse (Neef et al., 2001; Neef, Marckel, et al., 2005; Schweitzer & Sulzer-Azaroff, 1995; Solanto et al., 2001; Sonuga-Barke et al., 1992). Different explanations have been proposed to explain this finding. Schweitzer and Sulzer-Azaroff argued that children with ADHD prefer immediate rewards even when it means that they will receive less overall reward. By contrast, Sonuga-Barke et al. suggested that these children are delay averse, behaving in a way to reduce overall levels of delay. They also suggested that the children

fidget in the classroom to help pass time more quickly and minimize the perceived delay until they can escape from the situation. If so, the children's choices on the delay task and their activity in the classroom are functionally similar, or are maintained by the same reinforcement (Sonuga-Barke, 1994). This view is supported by data in the current study, which found that the children more likely to choose SSR also exhibited more gross motor behavior in the classroom than did the children who preferred LLR. However, the children's choices on the delay task did not correlate significantly with occurrences of inattention, inappropriate vocalizations, or inappropriate use of materials.

In the problem-difficulty task, the children with ADHD features were more likely than their peers to select the easy problem and therefore earned less overall reward. However, it is possible that more difficult problems took longer to perform and, thus, delayed reinforcement more than easy problems. The present study did not control for this possibility. The difficulty of the math problems were calibrated for each child, so differences in children's choices cannot be due to differences in mathematical ability. Children who chose the easy math problems also engaged in more gross motor behavior, inattention, inappropriate vocalizations, and inappropriate use of materials. Future research should determine if these behaviors and choices are maintained by similar reinforcement. If so, it is possible that behavior therapies that target the children's impulsive choice making may generalize to improve the children's classroom behavior.

The present research replicates and extends the Solanto et al. (2001) study in a number of ways. We replicated Solanto et al. 's finding that laboratory measures of impulsivity correlate with direct measures of classroom behaviors that characterize ADHD. However, two key differences are notable. First, whereas Solanto et al. found significant correlations between delay task measures and classroom measures of interfering behaviors and gross motor behaviors, the present study obtained significant correlations only for gross motor behaviors. It is possible this discrepancy is due to the observational category "interfering behaviors" in the Solanto et al. study being broader than the categories "inappropriate use of materials" and "inappropriate vocalizations" in the present study. Neither this study nor Solanto et al. found laboratory measures on delay tasks to correlate with classroom measures of inattention.

Second, we included a separate laboratory test of impulsivity: a choice between easy problems with small reward and difficult problems with large reward. The CTSC scores correlated at moderate to high levels (−.461 to −.661) for all ADHD indicator behaviors observed in the classroom. This yielded measures of shared variance (r^2) between 21% and 44% compared to r^2 values of 13% and 14% for laboratory delay tasks and classroom behavior in the Solanto et al. study. It is possible that the higher correlations and proportions of shared variance found in the present study were due to the use of math problems rather than a mouse-click task in the laboratory tests. Most children have a history with performing math problems, and those with sensitivity to problem difficulty may also demonstrate behaviors in class related to avoidance of classwork that take the form of inattention, gross motor movements, and disruption. It is also possible that the larger samples of classroom behavior (250 min vs. 16 min) resulted in more reliable estimates of ADHD indicator behaviors.

Another noteworthy finding from the present study is that children's choices on the CTSC were slightly better predictors of classroom behavior than were the Conners' rating scales. This may not be surprising, because the CTSC is a direct measure of impulsivity, whereas rating scales rely on parent and teacher recall and are more vulnerable to bias. The CTSC has the further advantage of identifying environ-

mental variables that may promote impulsivity for an individual child (e.g., reward delay and problem difficulty) and the threshold at which an individual crosses over from self-controlled choices to impulsive ones. This can give specific direction to the design of interventions compared to rating scales that indicate only that a child is rated as having more ADHD features than the norm. For example, Neef et al. (2001) showed that children who behaved impulsively can be taught to choose LLR in the laboratory. These interventions should be transferred to home and school settings. If children are taught to engage in challenging work or to wait longer periods for desired rewards or activities, it is possible that they will also engage in less inattention, gross motor activity, and disruptive behavior. As further studies provide more information about the variables that affect a child's impulsivity and his or her "threshold" for self-control, the range of potential treatment options that directly target impulsive behavior may expand.

The CTSC and similar laboratory measures of impulsivity and self-control are a variation of functional behavioral assessment. That is, the tests assess the variables that are functionally related to impulsive behavior. Thus far, this line of research has focused on variables known to affect choice: response effort and reinforcer rate, quality, amount, and delay (Neef et al., 2001). However, other variables commonly included in functional behavioral assessments may also be important to examine (e.g., attention, access to tangible items, escape from demands, and sensory or automatic reinforcement) (DuPaul & Ervin, 1996). Thus far, researchers have used functional behavioral assessment to identify environmental variables or contingencies that influence only a small subset of behaviors that define ADHD. For example, Northup et al. (1995) and Umbreit (1995) showed that the disruptive behavior of children with ADHD was maintained by attention and escape or avoidance of schoolwork, respectively. Lewis and Sugai (1996) found that one aspect of inattention, off-task behavior, was a function of combined low peer and low teacher attention. However, *DSM-IV* (APA, 1994) identifies numerous behavioral topographies that are indicative of inattention (e.g., loses things, easily distracted, forgets things), hyperactivity (e.g., leaves seat, fidgets, excessive talking), and impulsivity (e.g., blurts out answers, difficulty waiting turn, interrupts others). To the extent that future research can identify behavioral functions for these separate behaviors that define ADHD, this may lead to a biobehavioral model of ADHD that views ADHD features as an interaction between biological factors that may predispose one to ADHD behaviors and environmental factors that reinforce them (see Mace & Mauk, 1995). This development would contrast with the status quo that views ADHD as a neurodevelopmental disorder that necessitates medical treatment (Barkley, 1997).

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